SOME FACTORS INDUCING CHANGE IN THE VEGETATION OF ROTTNEST ISLAND

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McArthur (1957) and Storr, Green and Churchill (1959), in describing briefly the vegetation of Rottnest Island as it is at present, paid little attention to its dynamics. This paper has therefore the purpose of discussing some recent changes in the vegetation and the factors responsible for them. The latter have been grouped under the headings of (1) coastal erosion, (2) human occupation and (3) interaction between fire and Quokka grazing.

For the location of place names the reader is referred to the map in the *Journal of the Royal Society of Western Australia*, 42 (3), 1959.

I. COASTAL EROSION

The erosion of the coast of Rottnest has three effects, which in turn result in changes to the vegetation: (1) the instability of beaches, (2) the increasing exposure of the centre of the island to salt spray, and (3) the detachment of headlands to form islets.

The mainland coast opposite Rottnest is relatively stable; sand removed from beaches in one season may be replaced in another. In contrast, sand removed from Rottnest beaches is liable to be lost for all time; hence raised beaches are much less common than on the mainland, as are consequently the plants that inhabit them: *Cakile maritima*, *Arctotheca nivea*, *Spinifex hirsutus* and *Tetragonia zeyheri*. Indeed, south coast beaches are denuded so rapidly that along the greater part of Salmon and Strickland Bays no plants can maintain themselves between the sea and the undercut dunes.

As the area of an island decreases, so do the amount and effectiveness of the shelter received by the vegetation from salt spray. No part of Rottnest is now free from strong salt-bearing winds. Since most of these winds blow from the vicinity of south-west, salt-sensitive vegetation is best developed at the north-eastern foot of ridges. These sites, however, are apt to be open to strong north-easterlies, which cross twenty or more miles of sea before reaching Rottnest, sufficient time for them to become charged with salt spray. The effect of such winds was demonstrated in the winter of 1959, when after a period of north-easterly gales, all foliage was killed on the north-eastern aspect of many *Acacia rostellifera* and other tall shrubs. Along the mainland coast north-easterlies are, of course, land winds and cause no comparable damage; hence the seaward approach of salt-sensitive vegetation is limited only by protection from the west. The prehistoric disappearance of Tuart Woodland from Rottnest was attributed by Storr *et al.* (1959) to increasing exposure.

All the stacks and islets round Rottnest are used to a varying degree by nesting and roosting sea-birds. Deposition of bird excreta

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has profoundly changed the vegetation of these islets. Most of the selerophyllous shrubbery that grows on adjaeent headlands of the main island has been replaeed by a lush growth of coprophilous plants, some of them indigenous, some exotie. The indigenous speeies eomprise two categories of plants, viz. (1) shrubby or herbaeeous sueculents, e.g., *Carpobrotus aequilaterus*, *Nitraria schoberi*, *Rhagodia baccata*, *Enchylaena tomentosa* and *Threlkeldia diffusa*, most of which are rare on the main island; and (2) mesophytic perennial herbs, e.g., *Lepidium foliosum* and *Lavatera plebeia*, neither of which oecurs on the main island. The exotie element eonsists solely of winter annuals and ineludes such speeies as *Erodium cicutarium* and *Malva parviflora*, whieh are rare or absent on the mainland of Rottnest.

II. HUMAN OCCUPATION

Permanent settlement on Rottnest began in 1838 with the establishment of a prison for aborigines. Land was cleared for roads and building sites and in an endeavour to make the island self-supporting in food. Until 1923, when the prison was closed, a considerable area had been eultivated for wheat, barley, fruit, vegetables and stoek fodder (Somerville, 1949). The land so used was mostly poekets of relatively good soil between Lakes Bagdad and Serpentine, on the slopes of Mt. Herschell, and round Garden Lake.

In the past a lot of timber, espeeially *Callitris*, was felled for building purposes and fuel. In recent times dead trees (*Acacia rostellifera* and *Melaleuca pubescens*) have been eut down and removed by the Rottnest Board of Control for firewood.

TABLE 1.—ORIGIN OF PRESENT VASCULAR FLORA OF ROTTNEST.

Category	No. of species		
	Indigenous	Exotie	Total
Trees and tall shrubs	8	0	8
Other shrubs	37	4	41
Perennial herbs	26	8	34
Winter annuals	38	47	85
Summer annuals	1	3	4
Aquatics	7	1	8
Total	117	63	180

All this elearing and thinning of the serub has provided a habitat for an ever-inereasing number of exotie plants. At present naturalised speeies eomprise 35% of the vaseular flora, most of them being small winter annuals (Table 1) whieh oecur ehiefly along roadsides and in eleared areas. Though their effeet on the physiognomy of the vegetation is negligible, their presenee has greatly modified the island as a Quokka habitat. A high proportion of these plants are palatable, and the earrying eapaeity of the island in the rainy season (April to Oetober) has been substantially inereased. For example, there was only one speeies of annual grass before settlement; now there are 19 (Storr, 1962).

From the beginning of settlement until the 1930s (when there was a dairy) livestoek were run on the island—pigs, horses, sheep

and eattle. Whether they had any lasting effect on the vegetation is unknown; though no doubt they eontributed to the opening up of the serub and the dispersal of introdueed plants.

Fires have been of common oeeurrence throughout the 140 years of settlement. In the last few decades of the 19th eentury they were deliberately lit in the western half of the island during Quokka hunts (Somerville, 1949). It is perhaps owing to these fires that what now remains of tall scrub in the west of the island eonsists entirely of *Acacia rostellifera*, a speeies that suekers profusely after fire. *Callitris preissii*, onee so charaeteristie of the island that it is still ealled "Rottnest Pine," is now redueed to a few trees in and around the Settlement. Another fire-sensitive tree, *Melaleuca pubescens*, has disappeared from most parts of the island away from the shores of the salt lakes. Generally, however, the effects of fire are intimately bound up with the severity of Quokka grazing; it is therefore better to discuss them together.

III. INTERACTION OF FIRE AND QUOKKA-GRAZING

On the mainland of south-western Australia the Short-tailed Wallaby or Quokka *(Setonix brachyurus)* oecurs in densely wooded swamps. Rottnest is therefore an atypieal habitat, hut in the absenee of competitors and predators, Quokkas beeame numerous enough for their abundanee to be notieed by the early travellers. No doubt their inereased density had affected the vegetation, the more palatable plants, for example beeoming less frequent than in similar situations on the mainland. But over the millenia some sort of equilibrium would have been established between the Quokkas and the vegetation. Such an equilibrium would have been drastically upset by the settlement of the island, the principal disturbing faetors undoubtedly being fire and changing density of the Quokkas. Fire, without the eomplieation of Quokka-grazing, has already been mentioned. Past ehanges in the density of the Quokkas are not so easily assessed, and in the absenee of other doeuments the writer has had reeourse to the files of the R.B.C. (Rottnest Board of Control).

Recent Changes in Quokka Density

It will never be known how plentiful Quokkas were before settlement. It is relevant, however, to point out that even if they were only, say, a quarter as numerous as now, they would still have been reekoned abundant by mainland standards of kangaroo and wallaby densities. Moreover, it was their faeees, rather than the animals themselves, that Volckerson in 1658, de Vlaming in 1696, and King in 1822, found abundant (Alexander, 1914 and 1916).

Following the establishment of the prison, Quokka numbers almost eertainly declined; for the aborigines were released eaeh Sunday to fish and hunt wallabies. In 1864 Rottnest hecame the summer residenee of the State Governor, and thereafter Quokkas were shot by vice-regal parties (Somerville, 1949). Old residents of Rottnest, with whom I have discussed the subjeet, agree that before World War I Quokkas were scaree in at least the eastern part of the island. It is noteworthy that Quokkas were not mentioned in a

report by R. E. Weir (then Chief Inspector of Stock) on the possibility of commercial sheep-raising on Rottnest in 1919.

The closing of the Aboriginal Prison and Government House brought the Quokkas little relief, for the island was thrown open to tourists, and Quokka hunting became a popular sport. G. V. Edwick,

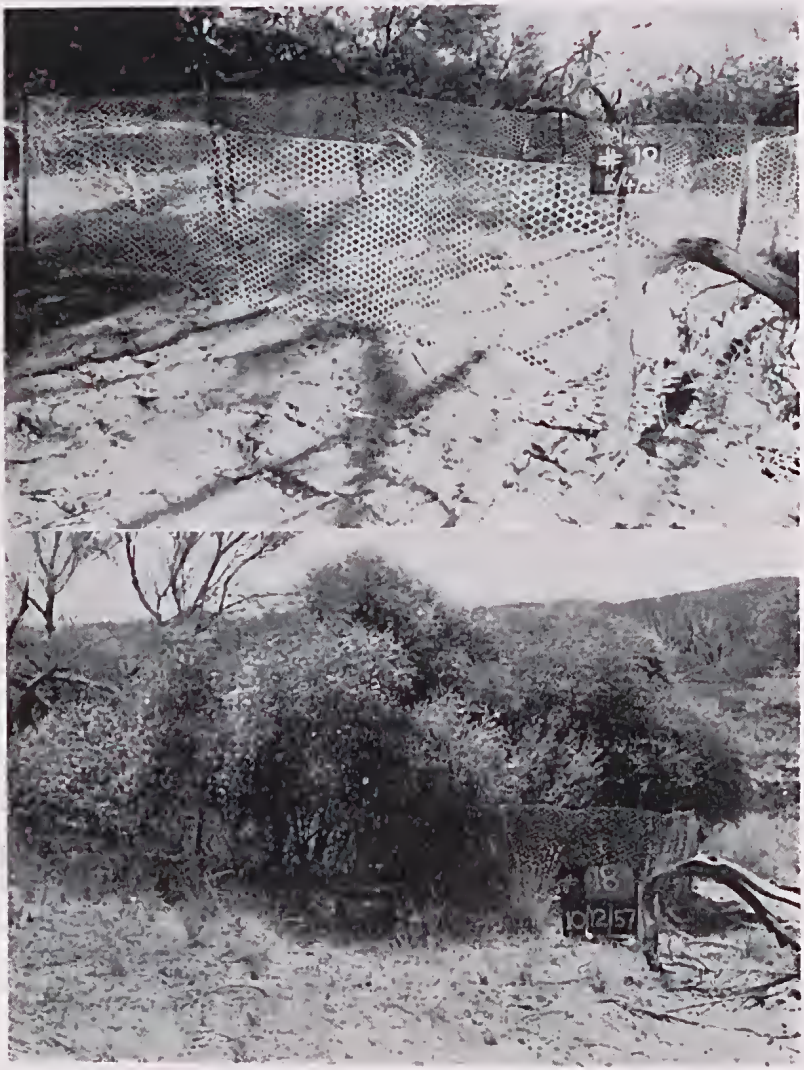

Fig. 1.—Demonstration of the effect of Quokka grazing on regenerating *Acacia rostellifera*. Exclosure No. 18, above Barker's Swamp, Rottnest Island: upper figure taken two months after the fire of February 1955; lower figure taken in December 1957, nearly three years after the fire, showing lush growth of *Acacia rostellifera* within fence and its absence outside.

—Photos J. W. Shield.

then butchering on Rottnest, complained in 1925 to the R.B.C. that wallaby hunters were disturbing his stock by walking through the bush at night with lights. In the following year J. B. Stark was appointed Honorary Guardian under the Game Act, 1912-13.

In October 1931, L. Glauert wrote to the R.B.C. that "the wallaby seemed to have recovered from the attacks to which it is subjected during the height of the tourist season when certain visitors indulge in ruthless and thoughtless destruction for the mere pleasure of killing." Next year we find the first reference to them as a pest, when H. T. Pearse, who was dairying on Rottnest, complained to the R.B.C. in 1932 of the damage done by Quokkas to his crops. He also described them as more numerous than he had ever known them previously. Similar reports of their great increase were common in the next few years. Reading these letters the writer received the impression that by 1935 Quokkas had attained their present high density on at least the eastern end of the island.

Fragmentation of the *Acacia* Scrub

In 1905 F. Lawson (Whitlock) wrote, "the interior of the island is clothed with very dense acacia scrubs, and were it not for 'rides' having been cut as means of communication, it would be quite impenetrable without the most severe exertion." R. E. Weir, in the report mentioned earlier, estimated that in 1919 *Acacia* scrub covered two-thirds of the island. L. Glauert wrote in 1928, "much of the island is clothed with dense wattle scrub tangled with creepers and undergrowth . . ." (Glauert, 1929).

By 1942, when the military map of Rottnest was published, the once almost continuous scrub had evidently been broken up into scattered copses, hardly more extensive than they were in 1955 when the writer began his researches on the island.

It seems that the major fragmentation of the *Acacia rostellifera* scrub took place at the same time as, or soon after the explosive increase of the Quokkas in the early 1930s. It remains now to examine more closely the combined effects of fire and high Quokka density on the scrub.

Regeneration of Scrub after Fire

In February 1955, 1,800 acres in the central western part of the island were devastated by fire. To study the effect of Quokkas on the revegetation of this country, the department erected 25 small exclosures, divided evenly among five major habitats (see Fig. 1). Each exclosure was visited monthly throughout 1955-56, the vegetation being compared within and outside the wire-netting. The complete results of this research (Storr, 1957) will not be repeated here; it will suffice to contrast the effects of low and high grazing pressure on both Dune and Acacia Scrub.

The dunes south-east of Stark Bay originally carried a dense shrubbery dominated by *Olearia axillaris, Acacia cuneata* and *Leucopogon parviflorus*. All of it being destroyed by fire, there was no shelter for the few Quokkas that survived; consequently these dunes were almost completely deserted for several months. Four

inches of rain fell in the week after the fire, and with higher than average autumn rainfall and relative freedom from Quokka grazing, vegetation soon reappeared—surprisingly fast in view of the strong winds that were sweeping the bare sand. First to regenerate (by germination of seed and shooting from undamaged rootstocks) were various monocotyledons: *Stipa variabilis, Poa caespitosa, Spinifex longifolius, Acanthocarpus preissii, Lepidosperma gladiatum* and *Conostylis candicans.* By the end of the first winter several perennial dicotyledons had also reappeared: *Scaevola crassifolia, Senecio lautus, Solanum simile, Thomasia cognata* and *Clematis microphylla* (all apparently by germination of seed); and *Leucopogon parviflorus* and *Acacia rostellifera* (by suckering respectively from stems and roots). By the following winter, with the germination of seeds of *Olearia axillaris, Westringia dampieri, Acacia cuneata* and *Diplolaena dampieri*, all perennial components of the Dune Scrub had returned. The cover then was still sparse and dominated by monocotyledons; but owing to the initially low density of Quokkas, there was a gradual return to a plant community similar, at least qualitatively, to that before the fire.

In contrast, the Dune Scrub originally covering the slopes of White Hill has failed to re-establish itself, the post-fire succession hardly proceeding beyond the monocotyledonous phase. In this area the fire did not jump the main Cape Vlaming road, and the unburnt scrub south from it to the coast provided the Quokkas with a refuge. From the beginning large numbers of Quokkas battered the regenerating vegetation north of the road, where even now shrubby elements of the Dune Scrub are restricted almost wholly to exclosures.

No Rottnest shrub recovers so well from fire as *Acacia rostellifera.* If only scorched, new foliage appears on the limbs; and if completely burnt out above the ground, the plant survives through the numerous suckers that emerge from roots. Indeed, owing to the shallow and extensive root systems, *Acacia* suckers may appear up to fifty yards away from the parent copse. In the long run, however, the fate of fire-induced suckers is decided by the Quokkas. At Stark Bay, where as noticed earlier, Quokka densities were low, *Acacia* copses not only recovered their previous extent but often advanced some distance into the surrounding grassland.

In the country north and east of Lighthouse Hill small pockets of scrub that escaped the fire harboured abnormally high numbers of Quokkas. And although the surrounding patches of burnt *Acacia,* as elsewhere, regenerated from the roots, the suckers were continually eaten down to the ground, and within a year or two had disappeared. Such areas of former scrub have been completely replaced by *Acanthocarpus,* tussock grasses, sedges, and unpalatable dicotyledons like *Thomasia cognata.*

Thus both Dune Scrub and Acacia Scrub, despite their marked adaptation to fire, fail to regenerate when heavily browsed. The monocotyledons that replace them clearly owe their advantage to their subterranean growing points.

It is significant that there are no plant communities on the mainland opposite Rottnest that are dominated by *Acanthocarpus preissii*. Here fires are probably more frequent than on the island, but herbivorous mammals are scarce or absent. It is not unlikely, then, that the present great extent of *Acanthocarpus* on Rottnest is a recent development. Although the events that led to the dominance of this plant are undocumented, their sequence may be reconstructed with some plausibility.

The botanist Cunningham, when visiting Rottnest in 1822, was impressed with the abundance of *Callitris*, whose dominance over the island was only occasionally broken by *Melaleuca* and *Pittosporum*. From his statement that these three "constituted the timber of the island" it may be inferred that *Acacia* was relatively uncommon. After settlement fire gradually eliminated such sensitive species as *Callitris preissii* and *Melaleuca pubescens*, whereas *Acacia rostellifera* increased until it generally dominated the scrub. *Acacia* was dominant by at least 1904 (the time of Lawson Whitlock's visit) and was still so in 1930 on the eve of the rapid increase in the Quokkas.

It is doubtful whether the original scrub with its scanty ground herbage could have supported as many Quokkas as it did later, when it was thinned and cleared and its "edge" was extended by human activities. Moreover, relatively unpalatable elements like *Melaleuca* and *Callitris* were being replaced by the more nutritive *Acacia*. More important, numerous alien plants were becoming established, many of them highly palatable. Meanwhile, the Quokkas were kept in check by human predation, and it was not until the late 1920s, when afforded complete protection, that they could numerically profit from this increased food supply. Their subsequent population increase has reversed the advantage that was enjoyed by *Acacia rostellifera* during the previous century.

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FROM FIELD AND STUDY

Nomenclature of an *Urodacus* Scorpion from Western Australia.—When the late Mr. L. Glauert discovered that an *Urodacus* scorpion from Broome had been described as *U. granifrons* Kraepelin, 1916 (*Ark. Zool.*, 10 (2): 39-42), and that the name was preoccupied by another species, *U. granifrons* Pocock, 1898 (*Ann. Mag. Nat. Hist.*, (7) 2 (7): 62-63), which was from the Geraldton area, he (Glauert, 1963: *W. Aust. Nat.*, 8 (6): 134-135) proposed the replacement name *U. kraepelini* Glauert, 1963, for K. Kraepelin's *U. granifrons* from Broome.

Unfortunately, Glauert had overlooked the fact that, in a somewhat inaccessible paper in Japanese, H. Takashima (*Acta Arach.*, Tokyo, 9 (3/4), 1945: 87-88) had discovered this same case of preoccupation and proposed the same specific name, *kraepelini*, as a replacement name.

This species of *Urodacus* from Broome should therefore be referred to not as *U. kraepelini* Glauert, 1963, but as *U. kraepelini* Takashima, 1945.

—L. E. KOCH, W.A. Museum, Perth.

Second Record of a Ringed Arctic Tern in South-Western Australia.—The Arctic Tern *(Sterna maerura)* breeds in the Arctic and Temperate regions of northern Europe and America and makes a trans-equatorial migration to Antarctic seas during the southern summer. Occasionally birds which perish on either the outward or return passage are washed ashore in southern Australia. On May 15, 1956, a bird was found at Naval Base, south of Fremantle, which carried a Russian leg-ring showing that it had been marked as a juvenile on July 5, the previous year, on the White Sea, about 125 miles south of Murmansk (G. M. Dunnet, *C.S.I.R.O. Wildlife Res.*, 1, 1956: 134).

Now a second similar case may be recorded. On June 10, 1963, a ringed Arctic Tern was found by Mr. H. W. Nessworthy, of Mandurah, on the beach at Madora Bay (35 miles south of Fremantle). The ring bore the inscription of the State Natural History Museum, Stockholm, Sweden (no. 4007833), and it was learnt from the Officer-in-Charge of the Swedish Bird Ringing Centre that the bird had been ringed as a nestling on June 27, 1962, on the islet of Ekholmen (Lat. 59° 10′ N., Long. 19° 00′ E.) in the Archipelago of Stockholm, province of Södermanland, Sweden.

Thus both the Russian and Swedish ringed birds had succumbed on their way north after their first season in the Antarctic.